Single mode control of overhead transmission line conductor with a nonlinear absorber

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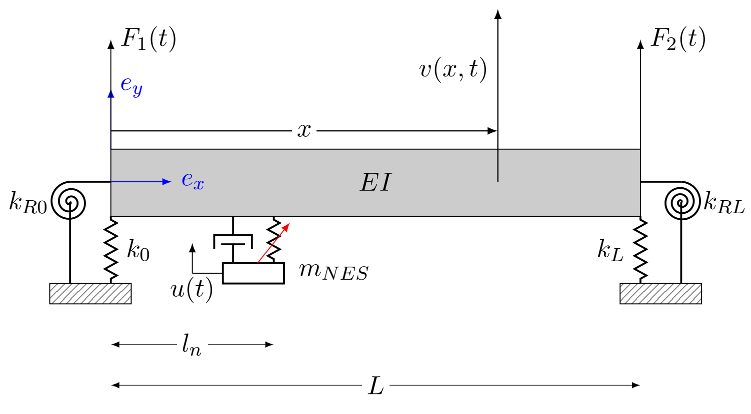
Summary. The possibility of controlling of oscillations of overhead transmission lines by a nonlinear absorber is studied. We consider a linear beam with elastic boundaries conditions in displacement and rotation under harmonic excitations. After complexification of the system variables, we study the system at different time scales. The fast time scale provides the SIM (Slow invariant Manifold). Then, a stability study of the SIM is performed. Studying the slow time scale leads to detection of equilibrium and singular points of the system. Finally, we compare the analytical results with numérical solution obtained with the finite element method (FEM)(Code_Aster).

Introduction

Galloping of overhead transmission lines brings large amplitude at low frequency oscillations [1]. This phenomenon occurs when there is an aerodynamic instability on iced conductors [1]. Since the 1930s several researchers work on a better understanding of this phenomenon and to predict the amplitude of oscillation depending on the wind parameters [2]. Some devices have been designed to mitigate the amplitude of oscillations caused by galloping. Torsion pendulum have been designed to reduce galloping vibrations [3]. Interphase spacers have been developped to avoid shot circuits and collisions between conductors [4]. On the other hand, there are some nonlinear dampers that can reduce aeolian vibration like Hydro-Quebec damper [6]. However, galloping mitigation with a nonlinear energy sink (NES) [5] have not been stydied yet. The NES has a small mass in comparison with the primary system and the two systems are coupled by a nonlinearity [7]. Hence, the main objective of this study is the behaviour of a cable coupled with a NES. We will locally modelise the cable with a linear beam with elastic boundary conditions in displacement and rotation. We conduct an analytical study of the system at different time scales. Complexification method of Manevitch [8] is used to understand the asymptotic behaviour of the system. We will validate the analytical results by comparison with the numerical solution obtained from the finite element method (FEM) Code_Aster.

Linear beam with elastic boundary conditions coupled to a NES

We consider the system of a beam with elastic boundary conditions coupled with a nonlinear oscillator. We can see on figure 1a the boundary conditions in translation k_0, k_L and rotation k_{R0}, k_{RL}. The nonlinear oscillator is coupled to the beam at the distance l_n from the extreme left part of the beam. One can see on figure 1b the restoring forcing function of the non-smooth NES. Only one modal coordinate of the beam wil be taken into account, for instance the coordinate of the first mode. The system is under external sinusoidal excitations $F_1(t)$, $F_2(t)$. We will consider the vertical displacement of the beam $v(x,t)$ and the vertical displacement of the oscillator $u(t)$. The effects of gravity are neglected.



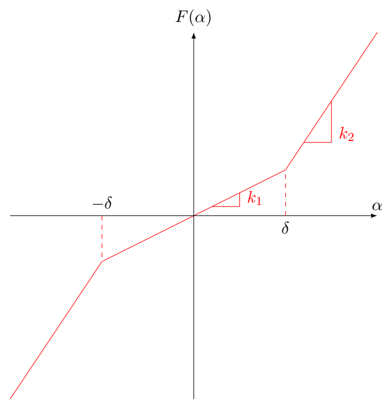
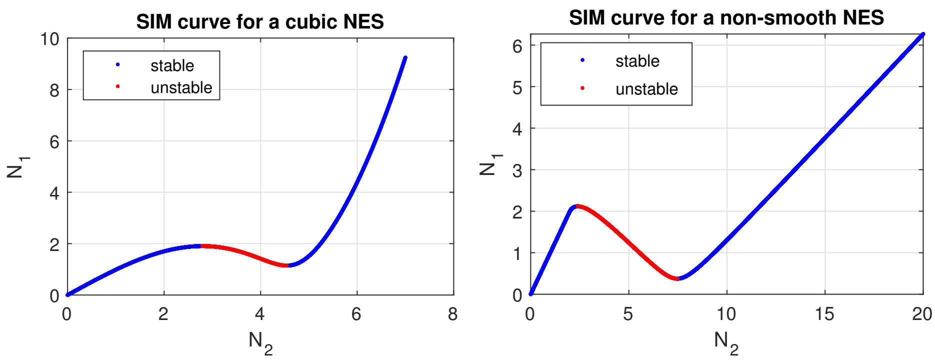


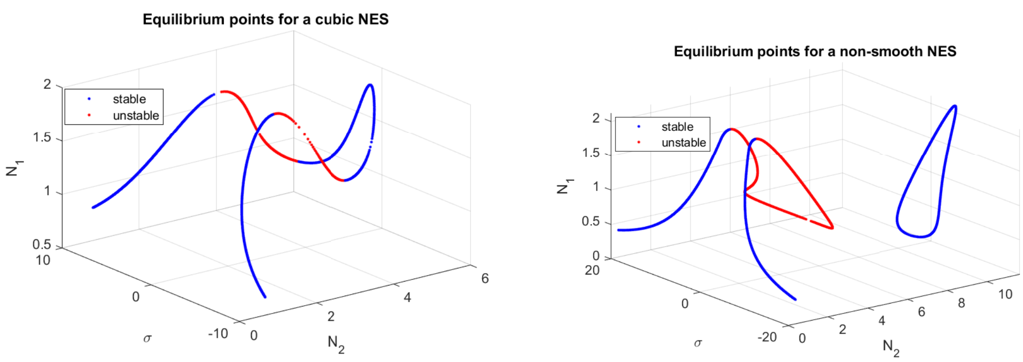
Figure 1: a) Linear beam with elastic boundary conditions coupled to a NES; b) non-smooth NES restoring forcing function.

The system behaviour around a 1:1 resonance is studied. We project the governing equations of the system on the first mode. The variables of Manevitch are introduced to study the enveloppe response of the system [8]. Different time scales are introduced and the system behaviour at each time scale is detected. By studying the dynamics at fast time scale we obtain the slow invariant manifold (SIM) [9]. One can see on figure 2 the SIM curve for cubic and non-smooth NES.
Then, we study the dynamics at a slow time scale and we obtain the equilibrium points depending on the excitation parameters namely, frequency and the amplitude [10]. On figure 3 one can see the equilibrium point depending on σ the normalised excitation frequency.



(a) (b)

Figure 2: The SIM of the system for a) cubic NES; b) non-smooth NES, N_1 and N_2 stand for energies related to the mode and the NES, respectively.



(a) (b)

Figure 3: Equilibrium points in three dimensions (N_2,σ,N_1) for a) cubic NES; b) non-smooth NES, σ is the detuning parameter from studying the behaviour around a 1:1 resonance.

Finally, we can validate our theorical results with numerical integration with RK4 method and compare with FEM solution obtained with Code_Aster. The FEM enables to detect system response for a given σ and to compare its envelope with the analytical prediction. The developpements provide design tools for tuning parameters of the NES.

References

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